

<http://www.inf.ed.ac.uk/teaching/courses/plan/>

Planning in Context

Planning in the Context of
Domain Modelling, Task
Assignment and Execution

Lecturer: Austin Tate

Date Prepared: 24-Sep-2009

Literature

- **O-Plan Papers** <http://www.aiai.ed.ac.uk/project/oplan/>
- Tate, A., Dalton, J. and Levine, J., *O-Plan: a Web-based AI Planning Agent*, AAAI-2000 Intelligent Systems Demonstrator, in Proceedings of the National Conference of the American Association of Artificial Intelligence (AAAI-2000), Austin, Texas, USA, August 2000. (2 pages)

- **Optimum-AIV Papers**
<http://www.aiai.ed.ac.uk/project/optimum-aiv/>
- Tate, A., *Responsive Planning and Scheduling Using AI Planning Techniques - Optimum-AIV* - in "Trends & Controversies - AI Planning Systems in the Real World", IEEE Expert: Intelligent Systems & their Applications, Vol. 11 No. 6, pp. 4-12, December 1996. (2 pages)

- **Other Practical Planners**
- Ghallab, M., Nau, D. and Traverso, P., *Automated Planning – Theory and Practice*, chapter 19, 22 and 23. Elsevier/Morgan Kaufmann, 2004.

Planning in Context 2

Literature

These 2 short papers will give an overview of some practical planners originating in AIAI at the University of Edinburgh which are in practical use.

The whole of the IEEE Intelligent Systems Trends and Controversies will be used for later reading, but for this lecture, just read the Optimum-AIV description.

O-Plan has been used for a range of practical and research tasks. It was developed from 1983 to 1999 and still runs as a planning service over the web

Optimum-AIV is in use by the European Space Agency for Assembly, Integration and Verification (Test) planning for the Ariane Rocket payload bay. Its design was based on O-Plan algorithms.

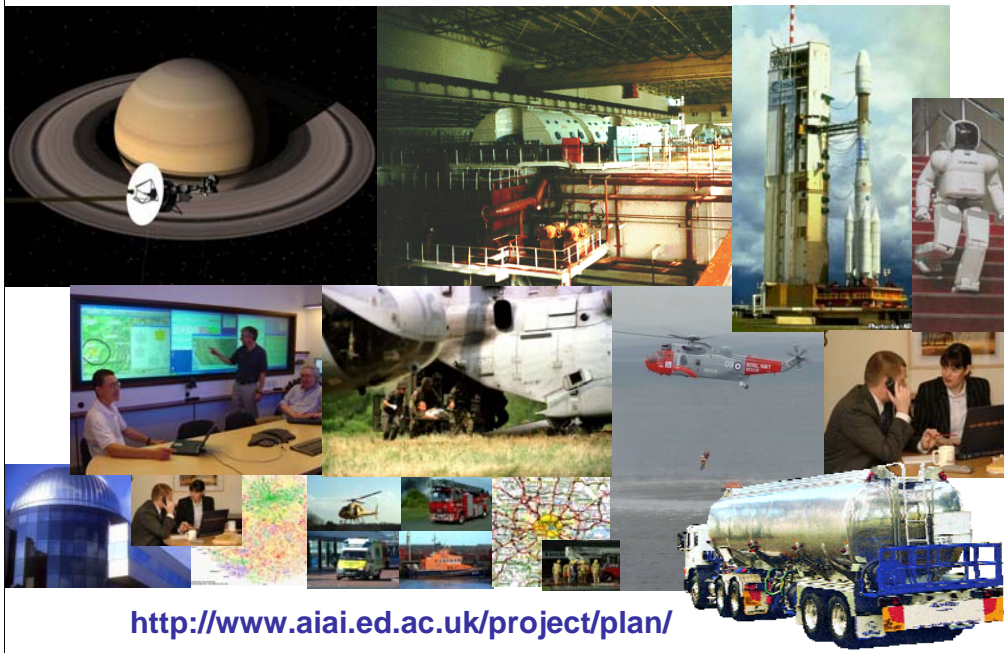
Further practical planning systems are described in several chapters of the course textbook... e.g. chapters 19, 22 and 23.

Malik Ghallab, Dana Nau, and Paolo Traverso. *Automated Planning – Theory and Practice*. Elsevier/Morgan Kaufmann, 2004.

Overview

- Practical AI Planners
- Planning in the context of execution
- Nonlin
- O-Plan
- Optimum-AIV
- I-X/I-Plan
- Planning++

Edinburgh AI Planners in Productive Use



1975 – Nonlin – UK CEGB - Electricity Turbine Overhaul Procedures

1982 – Deviser based on Nonlin – NASA JPL – Voyager Mission Planning

1996 – OPTIMUM_AIV based on O-Plan – ESA Ariane IV AIV for payload bay

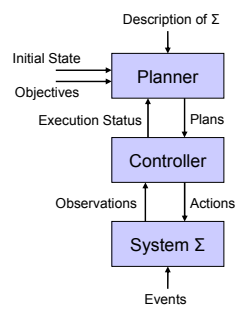
1996-present – Search and Rescue – UK RAF and USA JPRA

Commercial applications for Nynas tanker scheduling and Edify for financial help desks

Overview

- Practical AI Planners
- Planning in the context of execution
- Nonlin
- O-Plan
- Optimum-AIV
- Planning++

Dynamic Planning



- problem: real world differs from model described by Σ
- more realistic model: interleaved planning and execution
 - plan supervision
 - plan revision
 - re-planning
- dynamic planning: closed loop between planner and controller
 - execution status

Planning in Context

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Slide introduced in lecture 1 shows that planning systems are often used in a context where execution of plans is to be done.

Nonlin (1974-1977)

- Hierarchical Task Network Planning
- Partial Order Planner
- Plan Space Planner
- Uses State-Variable (Functional) Representation
- Goal structure-based plan development - considers alternative “approaches” only based on plan rationale
- QA/Modal Truth Criterion Condition Achievement
- Condition “Types” to limit search
- “Compute Conditions” for links to external data and systems (attached procedures)
- Time and Resource Constraint checks

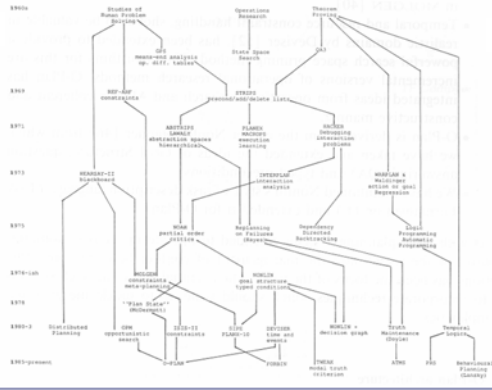
- Nonlin core is basis for text book descriptions of HTN Planning

O-Plan (1983-1999) Features

- Domain knowledge elicitation and modelling tools
- Rich plan representation and use
- Hierarchical Task Network Planning
- Detailed constraint management
- Goal structure-based plan monitoring
- Dynamic issue handling
- Plan repair in low and high tempo situations
- Interfaces for users with different roles
- Management of planning and execution workflow

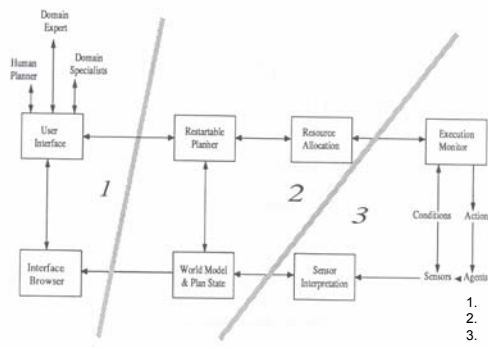
O-Plan has been used for a range of practical and research tasks. It was developed from 1983 to 1999 and still runs as a planning service over the web.

O-Plan (1983-1999) Features



Planning in Context

O-Plan Project Components

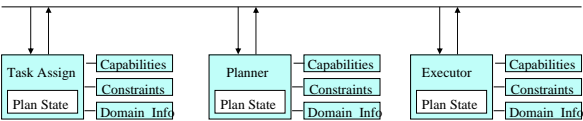


1. User Interface
2. Core Planner
3. Execution System

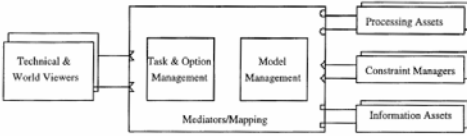
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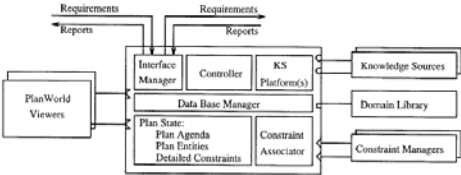
O-Plan 3 Levels



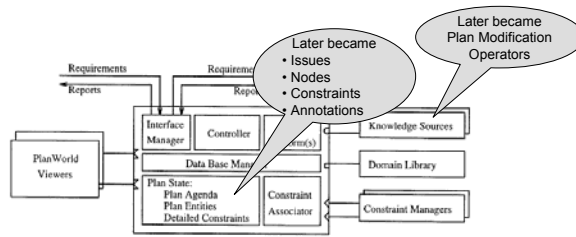
O-Plan Agent Architecture



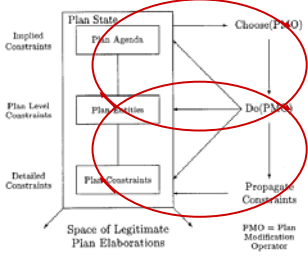
O-Plan Agent Architecture



O-Plan Agent Architecture



O-Plan Planning Workflow



O-Plan Unix Sys Admin Aid

Volume groups example

This example has O-Plan produce a shell script for removing a volume group.

To remove a volume group with the vgremove command, it is first necessary to remove all logical volumes from the group and all but one physical volume. To remove a logical volume, it is necessary to unmount any file system on it.

The volume group in the example is named vgl. The logical and physical volumes in the group have names lv1, lv2, ... and pv1, pv2, ... respectively. File systems have names fs1, fs2, ... and we assume that they are mounted on the corresponding logical volumes (fs1 on lv1, fs2 on lv2, and so on).

The volume group contains:

- 2 logical volumes.
- 3 physical volumes.

Plan Produce a plan to remove the volume group.
Reset Undo all changes to the form.

[Get Action](#)

VG results

O-Plan version 3.3+
Release date: 01-Aug-00
Build date: 14-Aug-00

Planning statistics:

in-am-cycles	= 37
in-opts-chosen	= 2
in-opts-remaining	= 3
in-potions	= 2

Script:

```
#!/bin/sh
/usr/mount fs1
/usr/sbin/lvremove -f lv1
/usr/mount fs2
/usr/sbin/lvremove -f lv2
/usr/sbin/vgremove vgl pv1
/usr/sbin/vgremove vgl pv2
# physical volume pv3 will be removed automatically
/usr/sbin/vgremove vgl
xx -t vgl
```

[The TV file](#)
[Make a comment](#)

O-Plan MOUT Task Description, Planning and Workflow Aids

The image displays three screenshots of the O-Plan software interface, illustrating the process of task description, planning, and workflow aids.

Left Screenshot: O-Plan Task Assigner - COA 2 Definition

Objectives

1. evacuate injured (Action: Abyss)
2. evacuate injured (Action: Barnacle)
3. evacuate injured (Action: Calypso)
4. repair gas leak (Action: Barnacle)
5. (Action:)

Situation

Weather	Time Limit	Read Delta	Read Abyss	Read Barnacle	Read Calypso
clear	24	open	open	open	open

COA objectives

COA	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5
1	Evacuate injured Abyss	Evacuate injured Barnacle	Evacuate injured Calypso	Repair gas leak Barnacle	

Middle Screenshot: O-Plan Task Assigner - COA Evaluation Matrix

Define meta: COA-1

- Split COAs: Split
- Add to task: Add
- Set authority: Auth
- Generate plan: Plan
- actions in plan: 13
- levels in plan: 1
- longest path length: 113
- minimum duration: 17 hrs
- effectiveness: 77%
- Address issues: 3
- View plan: View

COA objectives

COA	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5
1	Evacuate injured Abyss	Evacuate injured Barnacle	Evacuate injured Calypso	Repair gas leak Barnacle	

COA initial situations

COA	Weather	Time Limit	Read Delta	Read Abyss	Read Barnacle	Read Calypso
Default	clear	24	open	open	open	open
1	clear	24	open	open	open	open

Right Screenshot: O-Plan Planner - COA Evaluation Matrix

COA-2.1 COA-2.2 COA-2.3 COA-2.4

Advise planners: Advise Advise Advise Advise

Add constraints: Add Add Add Add

Set authority: Auth Auth Auth Auth

Generate plan: Regain Regain Regain Regain

actions in plan: 6 6 6 6

levels in plan: 2 2 2 2

longest path length: 69 57 57 41

minimum duration: 10 hrs 9 hrs 9 hrs 7 hrs

object types: 6 7 7 8

object values: 8 9 8 10

effectiveness: 89% 91% 91% 94%

Address issues: 4 4 4 4

View plan: View View View View

Select for return: Yes Yes Yes Yes

COA objectives

COA	Objective 1	Objective 2	Objective 3	Objective 4	Objective 5
21	Send medical supplies Abyss	Evacuate injured Barnacle	Send medical supplies Calypso	Repair gas leak Barnacle	
22	Send medical supplies Abyss	Evacuate injured Barnacle	Send medical supplies Calypso	Repair gas leak Barnacle	
23	Send medical supplies Abyss	Evacuate injured Barnacle	Send medical supplies Calypso	Repair gas leak Barnacle	
24	Send medical supplies Abyss	Evacuate injured Barnacle	Send medical supplies Calypso	Repair gas leak Barnacle	

Planning in Context

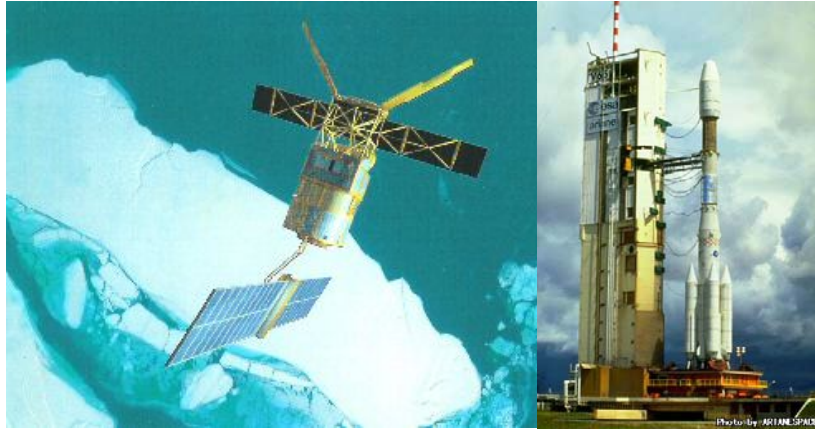
O-Plan Web Service

<http://www.aiai.ed.ac.uk/project/oplan/>

Check out AAI-2000 “Introductory Demo” Link

Password for some demos: “show-oplan”

Optimum-AIV



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Optimum-AIV is in use by the European Space Agency (ESA) for Assembly, Integration and Verification (Test) planning for the Ariane Rocket payload bay. Its design was based on O-Plan algorithms and earlier development of an AI planner for the ERS-1 Spacecraft.

Optimum-AIV (1992-4) Features

- Rich plan representation and use
- Hierarchical Task Network Planning
- Detailed constraint management
- Planner and User rationale recorded
- Dynamic issue handling
- Plan repair using test failure recovery plans
- Integration with ESA's Artemis Project Management System

Note the similarity to the AI features used in O-Plan.

Planning Research Areas & Techniques

- | | | | |
|---------------------------|-------------------------|--------------------------|----------------|
| • Domain Modelling | HTN, SIPE | • Plan Repair | O-Plan |
| • Domain Description | PDDL, NIST PSL | • Re-planning | O-Plan |
| • Domain Analysis | TIMS | • Plan Monitoring | O-Plan, IPEM |
| • Search Methods | Heuristics, A* | • Plan Generalisation | Macrops, EBL |
| • Graph Planning Alghthms | GraphPlan | • Case-Based Planning | CHEF, PRODIGY |
| • Partial-Order Planning | Nonlin, UCPOP | • Plan Learning | SOAR, PRODIGY |
| • Hierarchical Planning | NOAH, Nonlin, O-Plan | • User Interfaces | SIPE, O-Plan |
| • Refinement Planning | Kambhampati | • Plan Advice | SRI/Myers |
| • Opportunistic Search | OPM | • Mixed-Initiative Plans | TRIPS/TRAINS |
| • Constraint Satisfaction | CSP, OR, TMMS | • Planning Web Services | O-Plan, SHOP2 |
| • Optimisation Methods | NN, GA, Ant Colony Opt. | • Plan Sharing & Comms | I-X, <I-N-C-A> |
| • Issue/Flaw Handling | O-Plan | • NL Generation | ... |
| • Plan Analysis | NOAH, Critics | • Dialogue Management | ... |
| • Plan Simulation | QinetiQ | | |
| • Plan Qualitative Mdling | Excalibur | | |

There are many techniques which together offer support for rich planning systems.

Planning Research Areas & Techniques

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**Deals with whole
life cycle of plans**

In a later lecture we will seek to show that we can have a framework that allows many of these techniques to co-exist and be used in a sensible way.

A More Collaborative Planning Framework

- **Human relatable and presentable objectives, issues, sense-making, advice, multiple options, argumentation, discussions and outline plans for higher levels**
- **Detailed planners, search engines, constraint solvers, analyzers and simulators act in this framework in an understandable way to provide feasibility checks, detailed constraints and guidance**
- **Sharing of processes and information about process products between humans and systems**
- **Current status, context and environment sensitivity**
- **Links between informal/unstructured planning, more structured planning and methods for optimisation**

I-X/I-Plan (2000-)

- **Shared, intelligible, easily communicated and extendible conceptual model for objectives, processes, standard operating procedures and plans:**
 - I Issues
 - N Nodes/Activities
 - C Constraints
 - A Annotations
- **Communication of dynamic status and presence for agents, and reports about their collaborative processes and process products**
- **Context sensitive presentation of options for action**
- **Intelligent activity planning, execution, monitoring, re-planning and plan repair via I-Plan and I-P² (I-X Process Panels)**

I-P² aim is a Planning, Workflow and Task Messaging “Catch All”

- **Can take ANY requirement to:**
 - Handle an issue
 - Perform an activity
 - Respect a constraint
 - Note an annotation
- **Deals with these via:**
 - Manual activity
 - Internal capabilities
 - External capabilities
 - Reroute or delegate to other panels or agents
 - Plan and execute a composite of these capabilities (I-Plan)
- **Receives reports and interprets them to:**
 - Understand current status of issues, activities and constraints
 - Understand current world state, especially status of process products
 - Help user control the situation
- **Copes with partial knowledge of processes and organisations**

I-X Process Panel and Tools

Domain Editor

Process Panel

Map Tool

Messenger

I-Plan

I-X for Emergency Response



Summary

- Practical AI Planning
- Refinement Planning as a Unifying View
- Nonlin and O-Plan Features
- Planning++
- I-X/I-Plan Overview

Literature - Reminder

- **O-Plan Papers** <http://www.aiai.ed.ac.uk/project/oplan/>
- Tate, A., Dalton, J. and Levine, J., *O-Plan: a Web-based AI Planning Agent*, AAAI-2000 Intelligent Systems Demonstrator, in Proceedings of the National Conference of the American Association of Artificial Intelligence (AAAI-2000), Austin, Texas, USA, August 2000. (2 pages)
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